I have constructed the instrument which I propose to call the *Stereomonoscope*, as it exhibits in perfect relief a picture which *appears single* on the ground glass of the new instrument, and *as single* as the image of the camera obscura has always been supposed to be.

The instrument, in its present rough state, is undoubtedly very imperfect and susceptible of many improvements which time and experience will suggest. I present it as the result of a first attempt, hoping that it will be found curious as illustrating a new and interesting scientific fact and producing an effect quite unexpected in optics.

April 22, 1858.

Major-General SABINE, Treasurer and V.P., in the Chair.

Professor Julius Plücker, Foreign Member, was admitted into the Society.

The following communications were read :—

I. "On the Differential Stethophone, and some new Phenomena observed by it." By S. Scott Alison, M.D., Assistant Physician to the Hospital for Consumption. Communicated by Prof. Tyndall, F.R.S. Received March 22, 1858.

Engaged for some years in investigations into the phenomena of audition, I have become cognizant of some facts which I believe have hitherto remained unnoticed, and which are certainly not generally known to physicists and physiologists.

The first of which I shall treat is the restriction of hearing external sounds of the same character to one ear, when the intensity is moderately, yet decidedly greater in one ear than in the other, the hearing being limited to that ear into which the sound is poured in greater intensity. The sound is heard alternately in one ear and in the other, as it is conveyed in increasing degrees of intensity, and hearing is suspended alternately in one ear and in the other, as the sound is conveyed in lessening degrees of intensity.

Sound, as is well known, if applied to both ears in equal intensity,

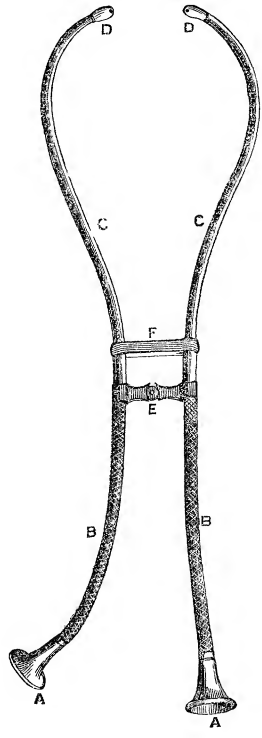
is heard in both ears; but it will be found, if the intensity in respect to one ear be moderately yet decidedly increased, by bringing the sounding body nearer that ear than the other, or otherwise, as by the employment, in respect to one ear, of a damper or obstructor of sound, or in respect of the other ear, by the employment of some intensifier, or good collector or conductor of sound, the sound is heard in that ear only which is favoured and has the advantage of greater intensity.

There is little doubt that this law holds with regard to sounds passing through the air, and carried to the ear in the ordinary manner, without the aid of any mechanical contrivance, as for instance those of a watch placed in front of the face; but as the restriction of hearing to one ear, and its suppression in the other, admit of being rendered more obvious by an apparatus that shall collect sound, prevent its diffusion through the air, and carry it direct to the ear, I propose to give the results of experiments made with an instrument which I have invented for hearing with both ears respectively, and which, as it is specially adapted for the auscultation of differences in the sounds of different parts of the chest, I have named the Differential Stethoscope, or Stethophone.

The results thus procured will be more satisfactory than those obtained by ordinary audition; a sound will be increased as a visual object is magnified by the microscope, and as both ears are similarly dealt with, a perfect parity of conditions will hold in respect of both ears.

The differential stethophone (see figure) is simply an instrument consisting of two hearing-tubes, or trumpets, or stethoscopes, provided with collecting-cups and ear-knobs, one for each ear respectively. The two tubes are, for convenience, mechanically combined, but may be said to be acoustically separate, as care is taken that the sound, once admitted into one tube, is not communicated to the other. The tubes are composed of two parts nearly equal in length, one near the ear-knob, made of metal (C); while the other part, near the collecting-cup, is made of metal wire (B), to impart flexibility. The ear-end is curved, so as to approach the ear, and is supplied with an ivory knob (D) for insertion into the meatus externus. The other end of the tube, being intended to collect sound, is supplied with a hollow cup, or

receiver (A) made of wood, or some such material. The mechanical construction of this instrument is borrowed from the stethoscope contrived by Dr. Caman of New York, and intended by its inventor for the purpose of hearing with both ears sounds emanating from *one* point, and collected into one cup. The two tubes are brought near together, a few inches in front of the face, by means of a connecting-bar (E), but calculated to prevent the transmission of sound from one tube to the other. This bar is supplied with a joint, which permits the tubes to be freely moved, as is necessary in applying the knobs to the ears. The two knobs are kept steadily in the ears by means of an elastic band (F) connecting the two tubes near the bar, already described.



The instrument being fitted into the ears, with the knobs directed upwards, and the cups being applied equally near to, or upon a sounding body, say the inflating lung, or a watch, and the conditions for collecting sound being the same, the sound is heard with both ears, as in ordinary hearing. But if one cup be removed a little, say a half or a quarter of an inch from the *watch* (for we shall now adopt it), and the other cup be left upon the watch, the sound is heard with that ear only which is connected with the cup placed upon the watch, and the sensation in the hearing ear is so marked, as to leave the mind in no doubt whatever that it is through that ear we become conscious of the sound. If the cup placed upon or nearer the watch, be removed a little further than the other cup, so as to be less favourably situated for collecting sound, say one inch from the watch, the ear connected with it becomes totally unconscious of sound, and the sensation of hearing is most unequivocally felt in the ear, and in that ear only, which but a moment before was utterly deaf to it. If one

cup be placed upon the middle of the watch, and the other on the edge, the watch sound is heard in that ear only which is connected with the cup placed upon the *middle*.

These experiments may be thus varied, and the result will in reality be the same, though apparently more remarkable. The watch, being held in the air, at the distance of about an inch from one ear, is heard distinctly beating into that ear only; but if the watch be now connected with the collecting-cup of the tube of the stethophone, inserted into the other ear, the sound, being greatly magnified, is heard in this ear, and in it only, the ear in which the sound had been primarily heard being now altogether insensible to it, or unaffected by it as far as our consciousness is concerned. The sensation of sound is transferred from one ear to the other, although the watch is allowed to remain in close proximity to the ear that is now deaf to its sound.

A watch placed upon or inside the cheek, is heard to beat in that ear which is nearer; but if the opposite ear be connected with it by means of one of the arms of the stethophone, or by a common flexible stethoscope, the watch sound is no longer heard in the ear nearer the watch, but in the ear further from it, which is now in reality brought into nearer connexion with it, by means of the hollow tube.

Sounds, produced in whatever material, are alike subject to this law, so far as my experiments have yet been made.

The medium in which sounds are produced does not alter this law. A watch ticking, or a bell ringing, either in the air or under water, affords the same results.

Sounding bodies give the same results when covered with soft or hard materials. A watch placed in one corner of a box, a few inches square, and an inch deep, is heard to beat in that arm of the stethophone only which is near it. By this means, and by successive movements of the instrument, and by attending to degrees of intensity, the exact position of the watch may be with certainty indicated. Or this may be effected by successively excluding those parts which fail to cause hearing in one of the ears.

The interposition of a body calculated to obstruct the sound at its entrance into one of the cups of the stethophone, causes the sound to be heard in that ear only which is connected with the cup which remains free from obstruction. This admits of ready proof, by

applying the two cups as much as possible equally on the middle of a watch about an inch above it, and by placing two fingers held together between one cup and the watch. When this is done, the watch is heard to tick into the ear that remains free from obstruction.

The removal of an obstructing body from one cup, while it is allowed to remain in operation with the other, causes sound which had been equally heard with both ears, to be heard in that one only which is connected with the cup freed from the obstructing body. Thus, if the fingers be interposed between the watch and the cups held equally over it, and the fingers be separated under one of the cups, so as to permit of atmospheric communication, the sound is heard in that ear only which is connected with this cup, and not at all in the other.

The effect of intensification of a sound in one ear depriving the other ear of all sensation of that sound, is interestingly shown by placing the *tubes* of the instrument across a block of wood with the cups hanging in the air. While both cups are left open, and a tuning-fork in vibration is placed between the two tubes, the sound is heard with both ears; but if one cup be closed with the hand, or with leather, and the other be left open, the sensation of sound is restricted to that ear connected with the closed cup. The sound in the tube connected with the closed cup is rendered more intense by the closure, the escape of sound is obstructed, and reverberation takes place. By virtue of the intensification, sensation is monopolized by one ear, and is lost in the other. The result and the mechanical conditions are much the same as in the experiments of Mr. Wheatstone with a tuning-fork held upon the head, presently to be referred to.

It is worthy of observation, that in order that a sound previously heard with, or in both ears, as in the above experiments, may be appreciated or felt in one ear only, it is not necessary that the stethophone, or other conducting instrument, be placed in the cavity of the meatus externus. It is sufficient for this result that the instrument be placed near the meatus, so as to give it an advantage of intensity over the opposite cavity. When the instrument is to be held only near the meatus, care should be taken not to touch the external ear, so that there may be no conduction by that part from contact, which would vitiate the experiment. The result is perfectly satisfactory and conclusive, although the remarkable sensation of

pouring in of sound into the ear is less marked,—a fact sufficiently intelligible from the diffusion of sound which must take place outside the ear, when the extremity of the tube is held there, and is not inserted into the meatus. It is therefore obvious that the restriction of hearing to one ear, under the conditions specified, is not due to closure of the meatus externus, the cause of the augmentation of sound in some experiments of Mr. Wheatstone, to be shortly referred to.

The remarkable phenomenon of the restriction of hearing to one ear, above described, seems not to be without important signification. It holds apparently in virtue of a law seemingly established for the purpose of enabling man and the lower animals to determine the direction of the same sound, with more accuracy than could be done had a judgment to be formed between the intensity of two similar sensations in the two ears respectively. All source of error is removed by there being only one sensation, although there may be two impressions. This law of a stronger impression in one ear, rendering us unconscious of a weaker, but similar impression in the other, has an analogue, though perhaps an imperfect one, in the sense of touch. Very strong impressions upon one part of the body cause such acute sensations, that minor impressions of the same kind upon another part are frequently not felt, in fact, produce no sensation.

The only observations bearing upon this law which I have been able to discover, are some by Mr. Wheatstone, in a paper entitled "Experiments on Audition," published in the 'Quarterly Journal of Science, Art, and Literature,' vol. ii. New Series, 1827. These experiments are intended to show the augmentation which the sensation of autophonic sound, and the sounds of a tuning-fork applied to the head, acquires when the ear is closed, although the perception of external sounds is diminished. Mr. Wheatstone shows that a vocal sound is heard louder in that ear that is closed, say with the finger, than in the other. He also shows, that the sound of a tuning-fork placed upon the head is heard louder in that ear which is closed than in the other which remains open, even though the tuning-fork may be brought nearer the open ear than the closed one. These experiments, Mr. Wheatstone says, prove that "sounds *immediately* communicated to the closed meatus externus are very greatly magnified;" and he adds, "it is an obvious inference, that if external

sounds can be communicated to act on the cavity in a similar manner, they must receive a corresponding augmentation."

This distinguished philosopher constructed the instrument named a Microphone, for the purpose of augmenting weak sounds upon this principle, *i. e.* the augmentation of sound by closure of the ears; and he informs us that it "is calculated for hearing sounds when it is in *immediate* contact with sonorous bodies," and that "when they are diffused by their transmission through the air, this instrument will not afford the *slightest assistance.*" This instrument is spoken of in connexion with the augmentation of sound, and not in reference to the limitation of sound to one ear, or to the comparison of sensations in the two ears. The remarkable, and, to the uninitiated mind, the wonderful fact, made known more than thirty years ago by Mr. Wheatstone, that a tuning-fork held upon the head close to an open ear is not heard in this ear, but in the opposite ear, provided it be closed with the finger, or by some other means, proved that sounds communicated to the skull were exclusively heard in the closed ear. In the case of the tuning-fork, the fact made known by Mr. Wheatstone is undoubted. The rationale of the phenomenon appears to be this:—The vibrations of the tuning-fork are communicated to the bones of the head, and through them to the ears, including their bones, cartilages, and contained air; but in the case of the closed ear, the vibrations are permitted no egress or escape, as in the open ear; reverberations take place, and the consequence is, that the sound is not duly moderated; and in virtue of the law I have just enunciated, the sensation of sound is restricted to the closed ear. When the tuning-fork, duly sounding, is held in the air, and not connected directly with the head, the closed ear remains insensible to it, and the sound is heard exclusively in the open ear.

Mr. Wheatstone's interesting observation relates to a head-sound not duly moderated, as in the opposite and open ear, and virtually more intense, and comes within the general law advanced in this paper, which embraces all sounds, whether internal or external, viz. that a sound of the same character in the presence of both ears, if conveyed by any means to one ear, or to the nerve of that ear, more intensely than to the other, is heard in the more favoured ear only.

It seems necessary, in Mr. Wheatstone's experiments, that the bones of the head shall vibrate freely; weak sounds, such as gentle blow-

ing, will not succeed; and if the tuning-fork be placed immediately under the open ear, and passed upon the soft parts, little fitted for vibration, between the mastoid process of the temporal bone and the lower jaw, the sound is heard in this ear, and not in the closed ear.

It may perhaps be well, before proceeding further, to acknowledge that I am well aware it has been long known that a very loud sound conveyed into one ear will render the other ear insensible to sound of a weak or low character. But the phenomenon which I have ventured to bring under the consideration of the Royal Society differs from this well-known and readily admitted fact in this important particular, that no very great loudness is required, and that no very great augmentation of sound in one ear over that in the other is necessary in order to restrict the sense of hearing to one ear, and to deprive the less favoured ear of the sense of hearing which it had previously enjoyed. A moderate, yet a decided increase of intensity is all that is required to remove the sense of hearing from the less favoured ear, and to cause the more favoured organ to be alone sensible to the sound.

When sound is proceeding into the two ears, but in consequence of its reaching one ear in greater intensity than the other is heard only in one ear, the sensation of hearing in the favoured ear, though strictly limited to it, is augmented by the sound entering the less favoured ear, although it entirely fails to cause a sensation there, or to produce a consciousness of sound in that organ. The more sound collected by the less favoured ear, as long as the amount is less than that conveyed to the other ear, the more the sensation of sound is augmented in the more favoured ear. The intensity of sensation in the more favoured ear increases in a ratio with the increase of sound in the less favoured ear, until the intensity of sound is the same, or nearly the same, in both ears, when the sensation experienced is the ordinary one of hearing with two ears.

This fact admits of satisfactory proof in this way:—A watch is placed on a table equidistant from both ears. The stethophone is applied to the ears; one cup is placed within an inch of the watch, while the other is turned away from it, at the distance of some inches. As the further cup is brought nearer and nearer the watch, the sound, *always* confined to the more favoured ear, is gradually and steadily intensified, until the two cups are, or are about to be, similarly

placed, at which moment the sensation ceases to be restricted to one ear, and has acquired its greatest intensity. This fact proves, that though the sensation of hearing be confined to the ear to which sound is communicated with greater intensity, we profit by the sound which is conveyed into the other ear, though failing to produce a sensation or a consciousness of sound there, by its serving to augment very materially the sensation of sound in the more favoured ear. The less favoured ear thus augments the sensation which we experience, at the same time that it fails to interfere with the aid which the sensation confined to one ear affords us as to the direction of external sounds.

The sounds of which we have been treating as differently affecting the two ears, according to the intensity with which they are respectively communicated, are of the same character, though differing in intensity. It is sounds of the same character only which exhibit the phenomenon of restriction in virtue of moderately different intensity. The sounds must emanate from the same sounding body, or from bodies sounding similarly. A little difference in *character* will cause the experiment of restriction to fail.

Thus, if two bells, differing considerably in character, be rung respectively in the two ears, one louder and graver than the other, the louder and graver sound does not render the other ear insensible to the weaker sound of the weaker bell. Both ears hear perfectly, but the loud, grave sound is heard in one ear, and the weak sound is heard in the other.

If, instead of one watch, we place two together, having sounds of different character, as for instance one low and grave, and another loud and sharp, and the two arms of the stethophone be placed over them respectively, the sounds of both watches are heard, but the sound of one is heard in one ear, and the sound of the other is heard in the other ear. The loudness of the sound in one ear does not increase the weakness of the sound in the other; or, in other words, the intensity of the sensation produced by the weak watch in the one ear is not reduced by the sensation produced by the loud watch in the other ear.

The sound of a watch ticking continues to be heard in one ear, although a large-sized bell is made to ring at the other; and I have not perceived that the sensation produced by the watch is at all

impaired by the bell. A whistling lung-sound heard in one ear, is not rendered less obvious by a loud blowing lung-sound in the other. A hissing murmur at the apex of the heart conveyed into one ear, and a rasping sound at the base conveyed into the other, are both heard without alteration in the ears to which they are respectively conveyed.

By virtue of these two laws,—1st, that sounds of the same character are restricted to that ear into which they are conveyed in greater intensity, and 2nd, that sounds differing in character may be heard at the same time in the two ears respectively, even if they be made to reach the ears in different degrees of intensity,—it is possible to analyse a compound sound, or one composed of two sounds, and to divide it into its component parts. In order to effect a division of a compound sound, it is only necessary that the two sounds of which it is composed may respectively be heard at certain points, in greater and lesser intensity, and that the respective cups of the stethophone be placed at these points. The ear connected with the cup placed where one half of the sound is in greater intensity, hears that half sound only, and the ear connected with the cup placed where the other half of the sound is in greater intensity, hears *that half* sound only. The sound is divided into two parts, and one is heard in one ear, and the other part in the other ear. For example, a compound sound composed of the two sounds of two watches placed together upon a table, with the unassisted ear is distinctly heard in its compound state, and cannot be divided into its two constituent parts. With the stethophone this is readily done. One cup is placed where the sound of one watch is in greater intensity, and the other is placed where the sound of the other watch is in greater intensity, and the result is obtained of one watch only ticking in one ear, and of the other watch only ticking in the other ear. The greater intensity of each watch-sound in one ear has rendered all hearing of it in the other ear impossible, and as each watch-sound in its greater intensity is conveyed to different ears, one is heard in one ear only, while the other is heard in the other ear only. Without the stethophone, or some such instrument, this analysis could not be made; the ordinary stethoscope will not succeed, for wherever it is placed it conveys the mixed or compound sound to the ear. If the naked ear be applied over or upon the

watches, the same result follows; and it is the same if instead of two arms of the stethophone we employ only one. This remarkable separation of the components of a sound may be effected also when the sounding bodies are enclosed in a box capable of transmitting sound, or when separated from us by the interposition of materials capable of conducting sound; and by successive trials and comparisons of intensity at different places, and by a process of exclusion of those parts which fail to cause sensation, the respective positions of two adjacent sounding bodies may be predicated. If, for example, we have two watches, A and B, enclosed in a box, and through one cup, A, we hear watch A, and with the other cup, B, we hear watch B, we may conclude that cup A is nearer watch A than cup B is, and so on. In the same manner we may auscultate the morbid sounds of the heart. By cup A, placed at the apex, and cup B placed at the base, we hear separately the morbid sounds of the two parts; for example, a blowing murmur at the apex in one ear, and a rasping murmur at the base in the other ear. This we are enabled to do, although at any intermediate point with the single ear, either with or without a stethoscope, we hear the conjoined two sounds. It is obvious that with the stethophone we not only succeed in separating sound, but that this instrument, or some similar contrivance, affords the only possible means of hearing, with two ears at once, sounds emanating from the same region or surface, for the sides of the head can be applied, of course, to the same sounding surface only in turn or succession. With this instrument we, as it were, place our ears in our hands, apply them where we choose, and listen with them both at adjacent or distant points of the same surface, at one and the same instant of time.

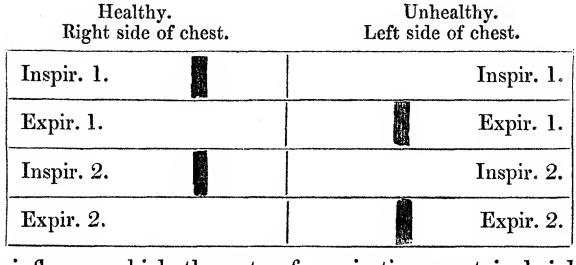
It is not unlikely that the property which the stethophone possesses of pointing out with precision where sound is most intense, may be very usefully employed. It seems possible that it might be turned to account in discovering the points where operations in military mining may be going on.

It is, however, in the practice of medicine only that the differential stethophone has been hitherto applied, and it may be here permitted to me to point to some of the chief purposes for which it is adapted, and for which it has been employed.

In respect to respiration, we may compare at once, and without

the inconvenience of moving the head, or the ordinary stethoscope, from place to place, the extent of the respiratory sounds in different parts, so that a very minute difference, an excess in one part or a deficiency in another, may with certainty be discovered. Differences in quality, such as softness or roughness, are readily recognized. The increased length and loudness in one part is accurately contrasted with the healthy conditions of another part. In cases where the *in*spiration has been very full in one place, in order to compensate for deficiency in another place, and where the *ex*piration was long and coarse in the deficient part, I have heard the inspiratory sound only in one ear, and the expiratory sound in the other ear. The sounds were respectively restricted to the two parts, and they alternated in a very marked manner. One part has remained silent while the other has been heard to sound, and this has been silenced when the other has awoke the ear.

The diagram represents the sounds occurring alternately in two sides of the chest in a *consumptive* patient. The dark spots represent the *sounds*.



The influence which the acts of respiration exert in heightening and lowering the murmurs in veins, say of the neck, in persons affected with a thin and watery condition of blood, is well exhibited by placing one arm of the stethophone on the chest and the other upon the veins.

When the respiration in two parts is alike in character, but decidedly louder in one part than in another, the sound in the weak side is lost. While this loss proves, in a very emphatic manner, the important fact of deficiency, it of course for the time deprives us of the opportunity of judging of the quality of the deficient inspiration; but this is readily obviated by removing the cup of the instrument from the full respiring part, and then the deficient respiration is immediately

heard through the other cup. Thus while the two sounds, being of like character, and one being more intense than the other, can be heard only in one ear at the same time, an admirable opportunity is obtained for contrasting the extent, and some of the qualities, of the sounds of the two parts, by placing the cups alternately and rapidly upon the two spots respectively. Vocal extussive resonance in two parts of the thorax, is well contrasted with the two tubes employed at once, or in immediate succession.

The sounds of the two sides of the heart, and of the valves of the two great arteries proceeding from that organ, are, by means of the stethophone, very advantageously dealt with. By placing it over the two sides of the heart, or the origin of the two arteries, we ascertain the character and loudness of the sounds of these parts. One cup being placed over the aorta, and the other over the pulmonary artery, if the sounds they collect differ in character, one sound is heard in one ear, and another in the other ear. We may have at the same moment an aortic murmur and a healthy pulmonary artery sound, one sound in one ear, and another sound in the other ear. But when it is desired to listen to each sound singly and in succession, the instrument will still be available, for the cups may be applied singly and in succession, thus affording ample means for contrast.

In cases of disordered heart, in which it is desired to discover whether the sounds of the two sides of the heart are synchronous, the stethophone affords the most satisfactory mode of investigating the fact. With it, we virtually place our two ears over the two sides of the heart; and if one side sounds at all after the other, the fact is made known, and the end of one sound and the beginning of another are clearly and distinctly defined. With the ordinary stethoscope this is impossible; for where one sound is heard, the other may be inaudible, and long before the head or stethoscope can possibly be adjusted at another part, the second sound has taken place, and is long since over.

In conclusion, I may perhaps be permitted to say, that the differential stethophone proves a great auxiliary in examining the heart with the cardioscope or sphygmoscope, which I had the honour to exhibit to this Society two years ago. While the latter instrument exhibits the movements of the heart, the stethophone informs us of their sounds, in a more complete manner than can be otherwise effected; and from the stethophone permitting of auscultating two

parts at once, and with the eyes directed to the chest, the relation of the movements and of the sounds, normal or abnormal, of this most important organ is very fully and satisfactorily made out.

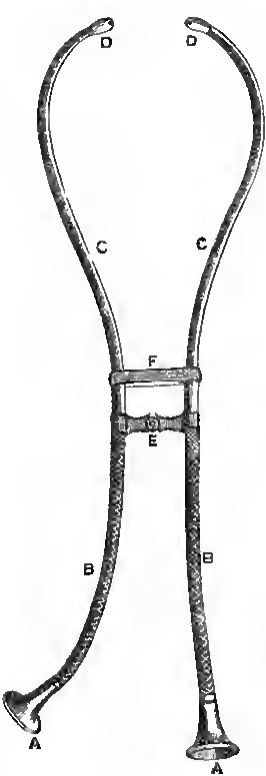
Postscript. Received April 22, 1858.

In connexion with that part of my paper which treats of the restriction of hearing to the closed ear, I desire to add the fact which I have ascertained within the last few days, that if one ear be closed wholly or partially at its external part, *i. e.* at the meatus externus, by disease or by congenital malformation, while the other ear is healthy, the sound of the tuning-fork, applied to any part of the head, is heard only in the closed ear. This fact holds, although the closed ear is totally unaffected by sounds conveyed through the external air.

I have further to mention the fact, that all persons, deaf in one ear, whom I have lately examined, with one exception, hear the sound of the tuning-fork applied to the head in that ear only that is deaf to external sounds. A man who has been totally deaf in one ear for thirty years, in consequence of a violent blow upon the head, had the tuning-fork applied over the forehead. He started, and said that he heard only in the ear which had been deaf during that long course of time. In such cases I have been disposed to believe that, amidst other lesions of the organ of hearing, there may be present an obstruction or closure, that a reverberation takes place, and that thus a restriction of hearing is secured for the diseased organ.

II. "On the Stratification of Vesicular Ice by Pressure." By Professor William Thomson, F.R.S. In a Letter to Professor Stokes, Sec. R.S. Received April 3, 1858.

In my last letter to you I pointed out that my brother's theory of the effect of pressure in lowering the freezing-point of water, affords a perfect explanation of various remarkable phenomena involving the internal melting of ice, described by Professor Tyndall in the Number of the 'Proceedings' which has just been published. I wish now to show that the stratification of vesicular ice by pressure observed on a large scale in glaciers, and the lamination of clear ice described by Dr. Tyndall as produced in hand specimens by a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